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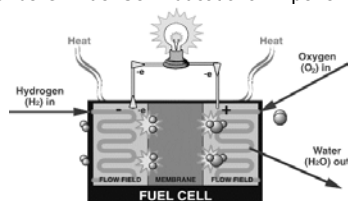
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Fuel Cell Technology Revolutionizing The Classroom

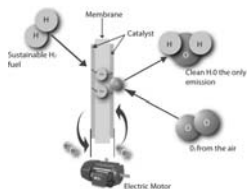
Hands-On Fuel Cell Educational Experiences



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Part of Preparing For The Hydrogen Economy Is Educating The Next Generation

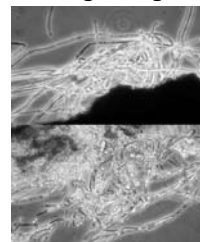
- To Date That Effort Has Been Largely Theoretical
- Students On All Academic Levels Will Not Have A Complete Understanding Of Fuel Cells Until They Have Experienced Them Physically



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In Many Ways Fuel Cells Behave Like Organic, Living Things

- Fuel Cells Breathe In And Out
- Fuel Cells Require An Approach To Balance Their Main Health Parameters: Temperature, Pressure, Humidity, Current, Etc
- These Parameters Will Effect Each Other And The Overall Performance Dramatically
- The Value Of Each Parameter Can Vary In Different Regions Of The Fuel Cell As Well As A Function Of The Time Or External Conditions
- These Behaviors Underscore The Need For Hands On Experience With Fuel Cell As A Supplement To Theory And Simulations

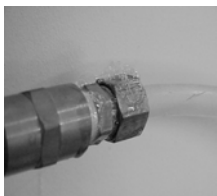


(Mold Happily Living On The Exterior Of A Fuel Cell Illustrates The Similar Operating Conditions Of A Fuel Cell And Organic Life)

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Safety Issues For Hydrogen Lab Classes

- Firmly Tighten, But Do Not Over Tighten, All Fittings In System
- Leak Check Fittings With A Sulfuratorant
- Conduct Hydrogen Experiments In A Well Ventilated Room With Upward Venting
- A Large Amount Of Hydrogen Trapped In An "Upside-Down Cup" Is Dangerous (Avoid This)
- Avoid Open Flames And Sparks If Free Hydrogen Is Present
- When Using Larger Quantities Of Hydrogen Consider A Hydrogen Detector With Alarm
- Shut Off The Valve On The Tank When The Hydrogen Is Left Alone
- Do Not Allow The Stack To Become Too Hot
- While Everyone Is Paying Attention To Hydrogen Safety, Don't Electrocute Them (Avoid Salt Water, Do Not Short Out The Stack, Be Cautious With Higher Voltage Systems)

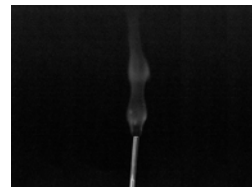


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Hydrogen Flame Demonstration

A Good Introduction To Hydrogen Safety

- Allow Students To Witness Hydrogen Flammability (Instill Respect Without Paranoia)
- "Invisible" Flame Is Not Invisible
- Very Low Temperature Outside Of Flame (Low Emissivity)
- Column Nature Of Flame
- Stress Upward Venting (Which Can Never Be Stressed Enough)



Small, Reversible, Fuel Cells Are A Safe Start

- *The Clear Plastic, Single Cell, Demos Are Becoming A More Popular Way To Introduce Fuel Cell Concepts*
- *More Use Can Be Made Of These Devices: Plot VI Curves, Vary Parameters*
- *Some Are Tricky To Use (The Instructor Should Practice Before Going To Class)*



Additional Equipment Needed: None (If Demo Has Solar Panel) Or Bottled Hydrogen And A Regulator (Recommended Even If Not Required)

Air Blower / Self Humidified Stacks Allow The Basics Of Fuel Cells To Be Explored

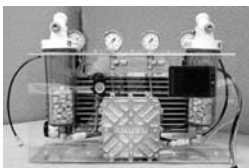
- *Reasonably Affordable*
- *Lack Of System Complexity Allows For A Trouble Free Lab Class*
- *VI Curves Can Be Generated*
- *Meaningful Things Can Be Bench-Top Powered*
- *12-24 Volts Reasonably Safe*



Additional Equipment Needed: Bottled Hydrogen, A Regulator And A Load Of Appropriate Voltage And Power

Complete Manual Systems Allow For An In-Depth Study Of Stack Issues

- *Modify Parameters One At A Time*
- *Map out Multi-Dimensional Performance Space*
- *Simulate Different Environmental Conditions (Temperature, Humidity And Gas Quality)*



Additional Equipment Needed : Hydrogen Tank And Regulator, Pressurized Air (Oil Free), Electrical Load

Automated Subscale Fuel Cell Engines Enable System Level Understanding

- *Bench Top Runs Of Vehicle Duty Cycles*
- *Anchoring Of Computer Models*
- *Place In Vehicles For Real World Driving Tests*
- *Power Portable/Remote Equipment (Robotics)*



Additional Equipment Needed : Hydrogen Tank And Regulator, Pressurized Air (Oil Free), Electrical Load (Can Be A Programmable Load With Driving Cycle Data Files)

Complete Vehicles Are The Ultimate Model Anchor

- *Validate Computer Models*
- *Look For Secondary Effects Leading To Model Discrepancies*
- *Understand Advantages And Limitations Of The Sub Systems And The Vehicle As A Whole*
- *Explore Backing-Up Equipment And Buildings.*
- *Test Mobile Gen-Set Applications*
- *Integrate Portable Electric Equipment Into Vehicle*



Additional Equipment Needed : Hydrogen Refilling Station Or Bottled Hydrogen And Bottle To Vehicle Adaptor.